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ABSTRACT

One of the challenges issued by the National Science Education Standards is for students to learn the content and process of modern scientific inquiry by engaging in research and entering science competitions. The Rockefeller University Precollege Science Education Outreach Programs (Science Outreach) provide access for about 70 students from diverse schools and for 12 teachers every summer. Researchers provide mentoring in the biomedical and physical sciences and Science Outreach provides modest amounts of funding for a few students, for all teachers, and for their action plans to take their research experience back into their schools to stimulate active learning for their colleagues and students. This paper focuses on preliminary data from standardized tests for students of Outreach teachers as an indicator that Science Outreach is attaining its goal of improving science education at the local level through the professional development of teachers. Preliminary findings indicate that students benefit when their teachers become immersed in the Science Outreach Program. (JRH)

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Teachers, Researchers, and Reform: Improving Teaching and Learning in High School Science Courses

by
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Teachers, Research, and Reform:
Improving Teaching and Learning in High School Science Courses[◆]

Abstract: One of the challenges issued by the National Science Education Standards, (NSES) is for students to learn the content and process of modern scientific inquiry by engaging in research and entering science competitions. In order to facilitate this reform, their teachers need to engage in exemplary Professional Development programs which meet or exceed standards issued in the NSES as well. Teachers and students need opportunities to gain mentored laboratory research experience and to have access to national and international competitions such as the Westinghouse Science Talent Search and the International Science and Engineering Fair (ISEF). The Rockefeller University Precollege Science Education Outreach Programs (Science Outreach) provide access for about 70 students from diverse schools and for 12 teachers every summer. Researchers provide *pro bono* mentoring in the biomedical and physical sciences and Science Outreach provides modest amounts of funding for a few students, for all teachers, and for their action plans - to take their research experience back into their schools to stimulate active learning for their colleagues and students. The Steering Committee and staff provide assistance at all stages. Science Outreach also hosts a regional ISEF which includes parents and the community.

Program evaluators conduct focus groups and interview students, teachers, and mentors to assess the process and provide feedback. As teachers implement their action plans and relate their research experience, their students begin to think of themselves as researchers, too. Indeed, the richest interactions occur in laboratories which mentor students as well as teachers. All

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teachers have recommended their students to the program and have grown more knowledgeable about local and national competitions. Ten students were semi-finalists in the 1995-1996 Westinghouse Science Talent Search and two finalists went on to become winners. Some students return and share their experience with their peers at weekly summer seminars for students and teachers. This paper focuses on preliminary data from standardized tests for students of Outreach teachers as an indicator that Science Outreach is attaining its goal of improving science education at the local level through the Professional Development of teachers.

Introduction: It is possible for potential teachers to receive a BA in science and an MA in science education without gaining laboratory research experience. Yet, the NSES present a vision for students which requires that they "combine processes and scientific knowledge as they use scientific reasoning and critical thinking to develop their understanding of science" (1). How are teachers to engage students in inquiry if they have not done so themselves? Not just learned about inquiry as a method, but really engaged in the process of scientific inquiry.

In New York State, Regents-Level Science courses require that **all** students learn the content of modern science by using the process of scientific inquiry, areas where many teachers and schools are unprepared. Whereas, traditional Regents multiple choice exams emphasized memorization of facts and vocabulary, the new Regents supports teacher-developed variances which introduce longer-term research projects and portfolio assessments. Engaging in research projects improves student learning and higher order thinking skills while assessing that work using portfolios should be a fitting indicator of what they know and are able to do. The need for teacher enhancement is great in New York City (NYC) where students perform below the state average. The paradox is: How are students in Regents Science courses to learn what they need to

know and be able to do in order to function in a modern democratic society if teachers and schools are hardpressed to provide the means?

Problem Solving: The problem can be addressed in small parts. Begun in 1992, Rockefeller University's Science Outreach Program has some documented success in this arena. Located in NYC, Rockefeller is a world-renown graduate biomedical research university. Science Outreach extends the apprenticeship method of training novice scientists to the training of teachers and their high school students. From 1992 to 1996, 31 teachers have spent at least one summer learning the content and process of modern scientific inquiry and have translated their experience into active learning for themselves, their students, and colleagues. As a result, increased numbers of their students are passing standard Regents Exams with higher average scores and teachers are developing approved Regents variances which teach and assess higher order thinking skills.

Science Outreach attracts secondary school teachers from NYC and its environs for the purpose of gaining research experience and evaluates past, present and future Outreach teachers to assess the degree to which they have developed as professionals and their students have improved as a result. Approximately five new and five returning teachers are trained each year such that returnees partner with and mentor new teachers. "New" refers only to the Program for Outreach teachers have widely diverse years of experience. Teachers gain: 1.) two, 8-10 week summer periods of mentored research experience in physics, chemistry, cell and developmental biology, neuroscience, microbiology, or immunology. 2.) support to implement improved, guided-inquiry classroom lessons and experiments. 3.) assistance to gain school commitment to ensure that implementation occurs and endures. 4.) ongoing professional development to disseminate their experiences and to stimulate lifelong learning. Outreach teachers serve on the

New York City Board of Education Curriculum Frameworks Committee, and work with its Office of Academic Initiatives and Assessment to prepare simple, inquiry-based experiments for inclusion in Regents portfolios. They submit inquiry-based lessons to the New York State Education Department to help implement the new Mathematics, Science and Technology Standards. 5.) information on science education reform to help implement recommended methods of teaching and assessment such as NSTA's *Scope, Sequence, and Coordination*, and *A Framework for High School Science Education, Project 2061*, the *National Science Education Standards, New Standards*. 6.) opportunities for their students to gain mentored research experience and classroom access to their Email accounts, Medline and Web resources. 7.) regular opportunities to meet and to give feedback ensuring that the Program remains effective and responsive.

Until introductory, undergraduate science courses become more inquiry-based and until preservice and inservice science teacher education follows suit, it will remain nearly impossible for teachers to convey the excitement of modern scientific inquiry to their students. Traditionally, *support systems* have eschewed training teachers as though they were graduate fellows responsible for their own continuous learning, in favor of staff development where *expert sources* fill *target teachers* with content without engaging in the difficult process of learning how to learn. Technology training falls in this disconnected arena as well.

Laboratory research integrates the content, process, culture, and ethos of science. Techniques are learned on a "need-to-know" basis and research, not class schedules, drives the time. Just as teaching and learning and research unite in a continuum of teacher-directed professional growth, so to do *supporters* and *sources* and *targets*. By the millennium, Science Outreach will produce 50 teachers who have in-depth research experience. If each teaches 100

students, then cumulatively, 20,000 students will have been exposed to inquiry-based learning. In-depth training of small numbers of teachers reaches large numbers of students in fundamental ways. Superficial training of large numbers of teachers may have little impact or endurance when technology changes.

Preliminary Findings - Regents Courses: Since 1992, formal evaluations support the objective that Science Outreach be effective with and responsive to teachers and students (2, 3, 4). In addition, the Director has conducted quantitative evaluation of performance on standardized tests for students of Outreach teachers and has collected reports by Outreach teachers who have developed approved Regents Biology variances. This preliminary data indicates that Science Outreach is achieving its goal of improving student performance through Professional Development for teachers. Evaluation will continue to include collecting similar data for present and future teachers and will compare that with data on students of past Outreach teachers, 16 of whom teach Regents, to measure if improved student performance occurs and endures.

Preliminary results indicate that students show impressive gains on Regents Biology Exams. For two schools in the South Bronx, the percentage of students passing rose dramatically as a result of instruction by their Outreach teachers. Each teacher's students are indicated in bold while the asterisk indicates the years the teacher was in the Program. One is a public school and the other is a parochial, all-boys' school. Both have 100% underrepresented minority populations.

Percent Passing Regents Biology for Two Schools in the South Bronx

	Baseline	Year 1	Year 2	Year 3	Year 4
Public	9%	**9%**	**20%***	**50%***	**76%* (in '94)**
Parochial	15%	**85%**	**94%***	**94%***	**(in '97 - TBA)**

For the public school teacher in her first year of teaching, the percent passing matched the baseline of 9% which had persisted for three prior years. It doubled after her first year in the Program, more than doubled after her second, and rose to 76% while supported by her own grant. The number taking Regents also increased from 6 out of 32 in Year 2 to 22 out of 43 in Year 3 while their average passing scores rose to 78% and 83%.

The parochial school teacher increased the percentage of her students passing over 6-fold during her first year. While she was not a new teacher, she had been a middle school teacher who was teaching high school for the first time. It increased to 94% and remained steady during her two years in the Program. Furthermore, the percent passing in her Regents Chemistry quadrupled from 20% to 85%, and all of her Regents Physics students are passing for the third year. Both are instituting a three-year, Regents Research course developed by a former Outreach teacher.

Another teacher collaborated with her school colleagues to design an inquiry-based activity following her first summer in the Program which became an approved Regents Biology variance. It replaces 35 points with a portfolio assessment. During the year, students complete four activities and a laboratory practical which counts toward half of their score on one section of the exam where they earn half credit for all correct answers.

One activity involves investigating plant tropisms. Students are given clear expectations, conduct library research and, as a group, choose a tropism for further study and write an hypothesis. They design controlled experiments with improvements facilitated during challenging teacher discussions. Once approved, they begin and collect data over five to ten days which they graph and analyze for their laboratory reports which are graded by a rubric. Discussion sections are written under test conditions ensuring that answers come from their own understanding. Experiments can be repeated to illustrate the importance of reproducibility.

The teacher reports: *The rationale for this switch to a teacher developed variance was to emphasize hands on laboratory experience and critical thinking, rather than rote memorization. In the past two years this has not changed substantially our passing rate, however, we feel that it is a more rigorous evaluation of the students' understanding of biology and the scientific method* (5). This philosophy supports Program goals.

Additional Preliminary Findings: In a small, all-girls' independent school on Manhattan's Upper East Side with 83% Caucasian and 10% Asian enrollment, another Outreach teacher is producing dramatic results in average SAT scores (6) where improved instruction and enrollment in Chemistry over two years coincides with the teacher's involvement in the Program.

Average SAT II scores for a private, all-girls' school on the Upper East Side of Manhattan

	Biology		Chemistry		Chemistry enrollment
Year	# Students	SAT II	# Students	SAT II	# Students
Baseline	7	470	0	-	5
Year 1 ('95)	5	470	**1***	**420***	**8***
Year 2 ('96)	3	470	**6***	**540***	**14***

The teacher entered the school **and** the Program in 1995. He never taught Biology, but he did start teaching Chemistry in 1995. His students are indicated in bold. The asterisk indicates his years in the Outreach Program. Whereas average achievement in Biology does not change, achievement in Chemistry improves. Concomitantly, the number of students taking the Biology SAT test decreases while the number taking the Chemistry SAT increases - as does enrollment in the teacher's Chemistry course. The challenge these findings present is to find more quantitative data of this nature, and over a longer term, which clearly indicate that the Program immediately and effectively enhances teachers to provide better instruction for their students as measured by scores and numbers of students taking Regents, AP, or Research Courses - or in SAT scores, etc. and that the gains persist. Many of these teachers also give workshops for their peers in classroom settings where they work on content knowledge and process skills. The networking that results from these professional opportunities is a valuable unanticipated consequence..

The final example indicates that even in the absence of formal grades or standardized tests, students of Outreach teachers show measurable gains in proficiencies and demonstrable competencies. One is a teacher at a public, alternative school in the neighborhood with 32% Caucasian/other, 33% Blacks, and 33% Hispanics. After his first year in the Program, the teacher changed his Science Research Methods class to make greater use of University resources, e.g. two scientists maintained contact with the class during the school year and students could use the library and access library resources from their classroom computer. As a result, the percentage of students officially declaring themselves ready to begin their science proficiency doubled from 33% the previous year to 66% after the change. Also, before he was an Outreach teacher, only graduating seniors had elected to become science proficiency candidates whereas,

after his first year in the Program that changed such that half of the candidates (10 out of 21) began their research at least one year prior to their projected graduation date. Two are Outreach students. The Program now has two teachers from this school.

Conclusions and Recommendations: These preliminary findings show that students benefit when their teachers become immersed in the Science Outreach Program. How many, how much, and for how long still needs to be determined. Although more data measuring outcomes on standardized tests for these students is needed before definitive conclusions can be drawn and recommendations made, it is safe to state that as Professional Development for teachers improves according to the recommendations in the NSES, student learning will improve. Many universities are examining their introductory science courses and science education courses in order to improve the teaching and learning of science. Many also have outreach programs supported at the highest levels and sustained by private, corporate, and public foundations. Mainly, they exist because of the altruism of thousands of volunteer scientists and technicians and the desire for teachers to advance as the professionals they are. Gifted and talented teachers and scientists endure. Therefor, more thoughtful, discerning citizens will emerge from these reforms. There is great hope for our system of education.

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1. National Research Council, National Science Education Standards. 105 (1996).
2. S. Chu, *Evaluation of the Science Outreach Program, 1994-1995*. Private communication from the Director of the Intern and Assistant Teacher Program, Bank Street College of Education, Columbia University. (1995).
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4. H. Etzkowitz and J. Alonzo, *Creating a Network: The Science Outreach Program Faculty Meetings at Rockefeller University*. Report of the Science Policy Institute State University of New York at Purchase and Stony Brook (1996).
5. Private communication.
6. Private communication.
7. Private communication.